Journal of the Society of Arts.

FRIDAY, DECEMBER 3, 1858.

EXHIBITION OF 1861.

The following letter has been addressed to the Foreign Corresponding Members of the Society:

Society for the Encouragement of Arts, Manufactures, and Commerce.

Adelphi, London, W.C., 1st December, 1858.

Sir,—I am directed by the Council of this Society to request your attention, as a Corresponding Member, to the enclosed resolutions,* having reference to another International Exhibition in London, in the year 1861, which have been made public.

It is perhaps unnecessary to remind you that the Society of Arts was the first to advocate the Exhibition of 1851, and the first to assert its international character.

The Society of Arts, from inquiries instituted, is satisfied that another Exhibition of Industry would be acceptable to the public of this country, and they believe to foreigners, and the Council are actively engaged in considering the best means of giving effect to the proposal.

Any Exhibition would be shorn of much interest and importance if confined to the produce of one country. It is of importance that the inhabitants of every country should become acquainted not only with what their fellow-countrymen can supply, but with what they can obtain from foreign countries.

The Council therefore desire to take the earliest opportunity of informing their friends in foreign countries of their views and desires, and though it would be rather premature at present to put forth any definite invitation for the year 1861, still it is only decorous to inform the industrial interest in every country of the proposal under consideration, and to invite their support.

Any communications which you may transmit, or which manufacturers or others may think proper to address to the Society, will receive the utmost attention, and materially aid the object which the Society has in view.

The Council would, therefore, be obliged if you would take means to give this communication every possible publicity.

In conclusion, the Council beg leave to say how happy the members of the Society will be to renew the agreeable and friendly relations established with so many distinguished persons in the year 1861.

I have the honour to be, Sir,
Your obedient humble Servant,
P. LE NEVE FOSTER, Secretary.

* See *Journal*, Vol. VI., page 333.

THIRD ORDINARY MEETING.

Wednesday, Dec. 1, 1858.

The Third Ordinary Meeting of the One Hundred and Fifth Session, was held on Wednesday, the 1st inst., Sir Thomas Phillips, Member of the Council, in the chair.

The following candidates were balloted for and duly elected members of the Society:—

Barber, Henry Charles
Benson, Henry Baskerville
Bonney, William Wolfe
Brocklehurst, Thos. Unett
Brown, Benjamin, C.E.
Clabburn, William H.
Clark, Thomas
Conybeare, H., C.E.
Cowie, Rev. B. Morgan
Danson, J. T.
Donald, William
Edwards, Frederick, jun.
Edwards, J. Passmore
Fletcher, John B.
Green, Daniel, jun.
Hartley, William, M.B.
Hudson, Stephen
Joubert, F.
Lankester, Edwin, M.D.
Merryweather, Richard M.
Mouat, Dr. Fred. John
Morgan, George
Neate, Charles
Nixon, Charles, C.E.
Norris, John G.
Ryland, Rev. J. H.
Scott, Andrew
Talbot, Capt. Hon. William
Wallace, Alexander, M.D.

The Paper read was—

ON COPPER SMELTING.

By Hyde Clarke, C.E.

Copper smelting is of considerable importance in England, not only because we smelt our own Cornish and other ores, but because we have also a large business in smelting foreign ores and refining foreign copper, which gives us a great command of the trade in manufactured copper; so that as well by our own advantages as the deficiencies of our neighbours, we obtain valuable results. Although the copper mines of England do not afford the rich ores of Lake Superior, or the Burra Burra, they abound in low sulphuret ores, which are easily smelted, and with the benefit of very cheap fuel, we are able to undertake the smelting of the rich carbonate ores of other countries on better terms than they can do it themselves. Many countries, rich in copper, have dear or scarce fuel, and dear labour, and must import their bricks and furnace cements, and thus it is found better to export the ore to the fuel, than to import fuel and carry it to the ore. Rich ores, too, in many cases are carbonates, which can be more conveniently smelted with the English sulphurets. Then, further, France, Belgium, and Holland are almost destitute of copper mines, so that the English have an opening there for manufactured copper, and compete in Central Europe with the Russian copper, or supply those countries with bar copper for refining.

With all these advantages it is still to be questioned whether the English copper trade has reached its height, or is free from vicissitudes. To suit the circumstances of local business a particular course of smelting by coal in reverberatory furnaces has been adopted; but this is not the most economical method, nor does it admit of the reduction of the lowest class of copper ores. It is quite possible, looking to the effective establishment of copper smelting in Chile, the United States, and Australia, to the abundant supply of rich copper ores abroad, and the competition of very cheap iron, that copper may be reduced in price, and thereby the working of the Cornish mines be threatened; but, on the other hand, if processes be adopted for the more economical reduction of copper, ores of lower produce or at lower rates can then be brought to market, and the reduction in price may be compensated. New combinations of copper, new alloys, as with silicium, will likewise open new sources of consumption.

At present copper smelting is a routine work, pursued on much the same plan as of old, and on the same general system in most of our works, followed out as a mechanical practice rather than as a scientific occupation; but the description of it is interesting, because it is continually undergoing modifications, which result in more economical working without much affecting the general system. There are several accounts of copper smelting, among which are those by the late Mr. John Vivian, the head of the great smelting firm, by M. F. Le Play, one of the most

eminent mining engineers in France, who has most minutely observed the processes; by Dr. Percy, before the British Association; by Professor Warington Smyth, at the School of Mines; by Mr. C. Low, who has introduced several improvements; by Mr. Napier, the author of great improvements in smelting; by Mr. John Arthur Phillips, a member of this society, and by a writer in the *Mining Journal*, but no account has been laid before this society, and I have therefore taken the opportunity, in contributing this account, to bring it up to the present day. It will be seen that in the main it will agree with the authorities referred to, but with the difference resulting from modifications which, formerly matters of theory and experiment, have now been more liberally adopted. There is, however, one inconvenience in such a paper, that it does not admit of the minute details which are necessary to give a complete view of the processes. Thus, Le Play has devoted a volume to the subject, describing each operation as closely as he could; and so, too, my own materials have to be abridged to meet the space which is disposable. It is much to be regretted, however, that we have not in English a work on this subject as copious as Le Play's, with the requisite drawings on a large scale. To produce this, however, would require, as in his case, the aid of a government department.

The copper smelting trade began in Cornwall, and was thence removed to South Wales, which until lately remained its sole seat, as it is its chief seat; but Liverpool having a great import of foreign and colonial copper ores and bar copper, has favoured the establishment of smelting works on the Mersey, and has a copper market, which is yearly growing in importance.

The classes of copper ores chiefly produced in this country are sulphurets which are made to average about 9 per cent. in the works. As sulphuret ores are more convenient for working in reverberatory furnaces, the smelters of South Wales and Liverpool are able to treat the carbonate ores from abroad, which are richer in metal, but less tractable than the sulphurets of copper.

The process of sampling copper ores in most of the copper countries of the world is now determined by the Cornish practice, which has been introduced, or is worked by Cornish samplers or by Welshmen trained under them. This process has been sufficiently described in works relating to mining, and provides for the ore of each mine or class being broken up about the size of a French walnut, or say ¾-inches, and formed into a separate pile. It is desirable the pyramidal pile should not be more than about a yard high, and the slope of the sides the natural batter determined by the stuff. A small pile is cut through with the sampling spade in four sections, by trenches, of about 8 inches wide at the base. The pile is cut thus,

```
                          a  b
                          c  d
but if a large pile, thus a b c  or  a b c d
                          d e f      e f g h
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In each section, as for instance that of a, two portions are taken with the shovel from bottom to top of the inner pieces of the section at each end. All these sixteen scrapings are brought together, forming so many vertical sections of the pile, and well mixed and ground up, being gradually reduced by dividing the mass into 4,

```
a b,  taking away  a
c d                  d
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and leaving only b and c, which are mixed and again divided into four, when the process is repeated till the whole produce of the sampling is brought to a manageable weight, from which the small samples for assay are taken, and likewise a drying sample, to ascertain the proportion of moisture in the ore.

Although a pile of copper ore under 100 tons is only divided into four, when above that quantity it is always further divided.

Copper regulus for sampling is broken to the same size as copper ore, but on account of the greater value of the article it is usual, unless the pile is a very small one, to divide it into six or more plots.

Argentiferous copper ore or argentiferous copper regulus is broken smaller or even ground up, as there is a greater chance of variation in the average sample.

Abroad, where the ores are shipped in a rough state, and labour is not available for breaking up the ores, they are sampled by taking one bucket of ores in ten or twelve, and reducing these to a small sample, by continued subdivision and subtraction, as in the case of the Cornish process.

In shipping ores from abroad for the English market the qualities of ores in bulk are separated by matting on board; but the richer ores, as silver ores, are shipped in small hide bags, of local make, or in bags of sacking sent out from this country, and in which there is a considerable trade.

In sampling, much, with all the care that is taken, may be done by a little mechanical skill on the part of the sampler in handling and managing his shovel, and in taking and leaving richer bits of ore, which he knows by eye, to get such a sample as he wishes.

In the case of ores in all climates, or whether carried by land carriage or sea, there is always some proportion of moisture imbibed, which affects the net weight, and is ascertained by a drying sample, which is tried in an oven and reduced to a dry state, the difference of moisture being taken as the difference of weight.

This is not always the true difference, as other portions are volatilized besides water, and the difference is in favour of the smelting. In hot countries, ores are affected by heavy night dews, and by the muleteers wetting the ores on crossing streams. Ores in ships generally imbibe moisture.

It is to be observed that the drying sample is taken at a different time from the assay sample. The maximum moisture of foreign ores imported into Swansea is stated by Messrs. Richardson and Co., the eminent ore agents of that town, and by other local authorities, as follows:—

Chile ores	28 drams, or	6 to 11	per cent.
Cobre ores.........	36	...	15	,,
Cuba precipitate	60	...	25	,,
Rough Chile regulus	9 to 10		3 to 11	,,
Rough copper ores	12	...	5	,,
Fine copper ores	22	...	9	,,

The minimum moisture abroad is :—

Rough regulus ...	1½ drams, or		¾	,,
Rough ore.........	2	...	1	,,
Fine ore...	10	...	4	,,

The process hereafter described is an ordinary course of working poor Cornish sulphurets mixed with rich foreign carbonates; the furnaces being about 14 feet by 11 feet inside dimensions.

I. Process of Calcining Ores.

The first course is to calcine the sulphurets, so as to get rid of some of the superfluous sulphur. There are many modes of effecting this. Where there is not a populous neighbourhood, the simplest mode, and one sufficiently effective, is to roast the ores in the open air in a pile with brushwood or small coal. This is done, for instance, in the Alten Works in Norway, belonging to the Alten and Quænangen Company.

In some works, the calcining furnace is much the same as the other furnaces. In others it only varies by side doors being provided for rabbling or spreading the charge over the hearth.

Messrs. Vivian, in some of their great works, use what are called baboons, an old form of calciner, fixed over the furnace, into which they discharge the calcined ore hot.

It is usual to make calciners with double beds, because as a lower heat is required than for melting, the flame

can, after being used on the lower bed of ore, be made to play on the upper floor or bed. A charge of ore is commonly laid on the top of the calciner in preparation for the upper bed.

Various plans have been suggested and tried for applying the spare heat of the smelting furnaces for calcining, but in England fuel is so cheap that it is preferred to burn coal rather than to resort to new and cumbrous arrangements. In many cases the wear and tear of the new furnaces would be more than the saving.

Under a calciner are vaults, called cubs, into which the calcined ore is let down and left to cool.

A calciner is sometimes very much larger in the floor than the other furnaces. Each charge put in a large calciner will be about four tons of ore fine dressed. It is first put on the top, and then passed in due course on to the upper floor, where the calciners are double. It is well spread over the floor, and about every four hours is turned over with a large rake, called a stirring rabble, introduced from the side doors. In six hours it is passed to the lower hearth through holes in the floor. In the first six hours' treatment little more is done than to warm the ore preparatory to the further calcining, as little or no chemical change takes place.

In the lower tier or hearth the charge is commonly left six hours, and is stirred every two hours, but as it is not stirred previous to discharge, it is only stirred twice. A charge is therefore passed through every six hours, but the time will vary according to circumstances. When the calcined ore is discharged into the cub, it is often cooled by water being thrown on it, and it is wheeled away to a heap for mixing, but in some cases is passed on direct to the furnace.

In smaller calciners than those here referred to, or in those of older construction, the charge will not be more than three or three and a-half tons weight. A difference in weight of charge will be compensated by difference in the size of the grate and the quantity of fuel consumed, so that the dimensions of the calciners might properly be adjusted by the proportions of calcining to the total work done.

For calcining the quantity of ore here mentioned with four charges a day, about one ton per day of coal would be burned, or about a quarter of a ton per charge of ore, or very nearly 1 cwt. per ton of ore; but as Sunday is a slack day, and the calciners are kept in heat, the rough consumption in a week may be taken at 7 tons, the number of charges at 24, and the weight of ore at from 90 to 100 tons. The number of working weeks in a year is about 48, but may be increased to 50.

If the ore calcined be a sulphuret of 10 per cent, though it is seldom so high, its constitution will be about, say:—

Copper	10
Sulphur	15 to 20
Silicious matter	45 to 55
Iron	20 to 25

About half the sulphur is expelled in the calciner or in the cubs, and a portion of oxygen is taken in and unites with the iron, and some chloride of sodium is obtained from the salt water thrown into the cubs.

Another class of ore may be thus composed:—

Copper	8
Sulphur	23
Silica	45
Iron	24

Mr. John Cameron, F.C.S., tabulates the results as follow:—

Original Form.		Converted into	
Sulphuret of Copper	8 Copper. 2 Sulphur.	8 Copper ... 2 Sulphur ...	Sub-sulphuret of copper.
Sesqui-sulphuret of Iron ...	21 sulphur 24 iron.	10 Sulphur..	Lost or replaced by
		5.40 Oxygen 12 Iron	Sesqui-oxide of iron.
		11 Sulphur.. 12 Iron	Sesqui-sulphuret of iron
Silica...........	45	45 Silica.	

In working a calciner, three men are employed for the day and three for the night, each gang under the foremen of calciners. The men are paid by the watch, and not by the charge, the operation being one of unskilled labour, and not requiring to be stimulated by piecework. The wages are from 14s. to 16s. per week. There is, in fact, no definite rule as to the state of the calcined ore, as it is not required to be exhausted of the sulphur, nor is any assay made to ascertain its condition.

II. Process.—Ore Furnace.

The second process is to put the calcined ore into an ore furnace.

The general form of a reverberatory furnace is about the same, and has remained so, from the earliest period of the establishment of copper smelting in this country by Sir C. Clerke. Some old drawings of Cornish furnaces are much the same in principle and general details as those of South Wales or Liverpool now. Further confirmation of this will be found in an interesting article on the early copper patents of Sir C. Clerke, in the "Mining Journal" of Nov. 27.

A furnace consists of a flat egg of the strongest fire-brick, supported by brickwork of ordinary bricks. Into this egg a large grate discharges the flame of a powerful fire, which passes along the upper inner surface of the egg, and is carried up a narrow throat or flue. At the bottom of the egg is laid the ore or metal to be operated upon. Such is the general structure of a furnace, but its details must be more closely examined.

It will be seen that its chief constituent parts are the grate, the furnace or hearth, and the flue.

The grate is a smaller structure added to the furnace at its back, open to the furnace on one side, and having on the three other sides walls roofed in at the top and open to the ashpit at the bottom. The size of the grate is chiefly dependent on that of the furnace; but it is varied by different engineers. According to an able practical authority, Mr. Alfred Trueman, C.E., the area of the hearth of the furnace being about 154 square feet, the area of the grate will be from 17 to 19 feet. The depth is not of so much importance as is the area of incandescent coal which supplies the flame. On one side of the grate is an iron feeding-hole, called a teazing pot, by which coal is thrown in. The grate is open to the furnace, but the communication is throttled by a thick wall called a bridge, which likewise forms the dividing wall between the grate and the furnace, and rises above the level of the hearth of the latter.

The ashpit under the grate allows the furnacemen to get down not only to remove the ash, but to rake the fire from beneath.

The furnace is of an oval or egg-shape but flat, and its capacity is diminished by sandbeds or bottoms. It consists, as already said, of a casing, which is formed of fire-bricks or silicious bricks, called the inside casing. The outer form of the furnace is, however, nearer to a square, and it is composed of less refractory bricks. This is called the outer casing, and the intervals between the inner and outer casings are filled in with old bricks.

On the hearth or floor of fire-bricks of the furnace, as already said, a bottom is raised for its protection. When a new furnace is started, it has to be annealed. This is done by keeping up a fire in the grate for about a fortnight, with the doors of the furnace off. No bottom has yet been put in. The doors are put up, and the furnace tested with a few hours good heat, to see whether there are any flaws or airholes. If found all right, and while the furnace is hot, a little slag, say sharp slag, is melted on the top of the bricks of the floor, say two inches in depth. Some sand is then thrown in gradually with the slag, the furnace being still in heat.

The first bottom is then put in, being fire-sand to the depth of about 18 inches. It is calcined for two hours, whereby the sand is consolidated, and the specific gravity increased. The men then level it with a rabble. The

bottom is then smoothed down with a beater, giving it a little fall to the tap-hole. The doors are then put up, and a strong heat is kept up for twelve hours. A little metal or ore is next thrown in, which is melted in, say, a quarter of an hour.

The sand is then thrown in for a second bottom, to a depth of, say, 4 to 5 inches, and this is calcined for four hours. It is then levelled with the rabble and smoothed down with the beater as before; the doors are put up, and the bottom is melted for ten hours, and next the doors are taken down, and some metal is put on and melted for, say, half-an-hour. The doors are taken down, and the furnace cooled black, that is, to a dull red heat, for three or four hours, when a full charge is put in and melted, and the furnace is cooled down again, and next three charges are melted in succession. The furnace is cooled down again, and thenceforth thoroughly started.

The bottoms constitute one of the most essential details in the working of a furnace. In South Wales blown sand (or sand driven on the shore by the wind) is used, because it is nearest at hand and readily obtained. As much as seventy waggon loads a day are used by some works. This sand is inferior, because it is mixed with shells consisting of lime, which flux, but it is supposed that in the blown sand the shells, being lighter, are winnowed, and that the proportion of silex is larger.

Abroad shore-sand cannot be used, and fire-sand is imported from England. Fire-sand is likewise employed in some of the Welsh works. Such sands are found in several parts of South Wales, near Swansea and Neath.

This fire-sand is nearly silicious, but shore-sand blown is thus composed, according to one analysis:—

Quartz and silica	86
Lime	5·7
Magnesia	·8
Alumina	1·6
Oxide of iron	1·2
Carbonic acid, traces of water, &c.	4·5

The following are notes on some fine sands, obtained inland, and used for bottoms:—

No. I.—Cwm Joy, near Swansea.

Silica	92
Iron and Lime	11

This proved very bad, and, while used, came up almost every week.

No. II.—Sand from near Breton Ferry and Neath.

Silica	92
Iron and Lime	8

This did well.

No. III.—Pembre.

Silica	93
Iron and Lime	7

This worked very well.

Iron is considered more objectionable in bottom sands than lime.

The consumption of best fire-bricks yearly, in a furnace of the size recorded, including grates, will be between 7,000 and 7,500.

A single furnace, of the size already given, and a stack 45 feet high, used up—

Best Welch Fire-brick	2,288
,, Scotch ,,	5,816
Common Welch Fire-brick	13,271
	21,375

The bottoms in an ore furnace will often last twelve months, but in a like furnace seven bottoms have been put in in the same time. The only cause assigned for this latter case, was that a stream of air came in through a hole in a door, and regularly cut the bottom, which parted and came up. In a roaster, however, the bottoms are always giving trouble. It is always desirable to keep the lower bottom as long as possible, and only to replace it when the furnace is out, or repairs are on hand. The lower bottoms may be worked for years. The upper bottoms may, however, require renewal in three days or in three months. The breaking of a bottom suspends the furnace for some time, as it has to be cut to pieces with flowing bars, and got up. Letting out a furnace only for a day causes such injury to the bottoms, that they sometimes have to be removed or renewed. This will happen at stock-taking, when the furnaces are let down. This is one inducement to keep a furnace always under fire.

These bottoms absorb a considerable quantity of copper, which is thereby kept locked up in the furnace, and this prevents the double disadvantage of dead capital and of uncertain quantity.

The furnace requires a bin or hopper at the top, to put in the charge of ore, and has a tap-hole formed at one side, which is only opened for letting out the molten regulus. The front door, for stirring and rabbling, will be described with the flue.

The outside casings of the grate and furnace are not dependent solely on the cohesion of the bricks, of which the fire-bricks are cemented with fire-clay and fire-sand, but they are fastened by cast-iron studs or upright posts of iron, a foot or two apart, and bound together at top by bars of iron, called cramps, or clamps. Thus, a furnace is bound together in an iron cage, but it does not nevertheless withstand the violent action of the fire.

The flue springs from the narrow front of the furnace by what is called the uptake, up which the flame proceeds, and the flame and smoke are thence carried to a short stack or down into the central culvert. The front door of the furnace is under this flue in the front wall, and when the furnace is at work, it is secured by a door or slab of fire-pottery, which can be removed to enable the smelter to work the charge.

The grate is, as stated, a square, hollow chamber. It has at the bottom two strong iron bars or sleepers. Regular furnace bars are not used, but loose bars of old iron are laid on the sleepers. The place of furnace bars is really supplied by a clinker bed. The coals commonly used for smelting in South Wales, erroneously described in most works as anthracite steam coal, include a considerable proportion of clinker, and advantage is taken of this to build up a porous red-hot substratum of clinker, by leaving always a considerable portion of clinker in the grate. On the top of this the coal is burnt, and the height of the clinker grate is kept down by getting out portions from below the ashpit, and more particularly when a large clinker has been formed. It is for this reason that loose bars are used.

This clinker grate is porous, and has channels through it, up which the atmospheric air passes, and is heated before reaching the burning coal in passing thence to the furnace. When needful for this purpose the clinker grate is opened up with a pricking bar from below. This method has one disadvantage, that small coal will run through a large channel without being consumed, but are wasted in the ashpit. This may be remedied by greater care.

One advantage of this method is that almost any kind of coal or slack may be used for smelting. Generally the coal is the refuse of the collieries, if any vend can be got for the larger coal, and slack has been exported for foreign collieries. Any free burning coal will do, if cheap enough, but if used alone it is rapidly burnt up. It will be seen that the coal has to perform a double function, to pour flame into the furnace, and to keep up the clinker grate, and therefore, where it can be done, it is found most useful to mix a free burning and a binding coal, so that the latter may clinker and bind together, besides giving its share towards the combustion. A coal altogether bind-

ing can be worked, but is not found good. Anthracite does not work well. A good mixture is one of binding and two of freeburning.

The best coals, binding and freeburning, are perhaps those of South Wales. Newcastle has good freeburning and some binding—the Lancashire coals are inferior. Artificial fuel has been used, but there is a prejudice against it, as the men do not like to handle large blocks or large coals, but like to have them ready broken.

In our works the supply is mostly obtained from collieries leased by the copper companies, and as the best qualities are sold for shipment, the smaller coal comes cheap, and but comparatively little attention is paid to its quality or consumption. There is most frequently no choice as to quality, and it is so cheap that its consumption is not closely supervised. It is, however, very doubtful whether slack is really economical, for good coal forms smaller clinkers, having less refuse in it, and is more economical of coal, whereas small coal and slack form very great clinkers, and interfere with the healthy working of the furnace, with good coal, the fire is pricked about twice in each watch, but with bad coal oftener.

With regard to the square form of grate, my opinionl is that there is a space not fully occupied by the fire, which is lost, besides the grate being there liable to injury, and in 1855 I suggested that the back should be rounded, and this has been tried.

In working the ore furnace, the charge will vary according to the class of ores, and the furnaces, and the weight according to the size of the furnace, from 3 to 3½ tons, or in large furnaces rather above, but dependent on the fusible proportions of the ore. Calcined ores are more favourable, but the practice is at this stage to introduce raw carbonates, so that the following will give a good specimen of a charge.

Calcined ore	36 cwts.	Raw ore 26 cwts.
Sharp slag	8 ,,	
Total	44	
Add	26	
	70	

The proportions of sharp slag may be made much higher, and of course that of calcined ore.

Of this total weight it is to be observed, the slag is seldom weighed, but is computed; the ore is counted to the men as 22 cwt. to the ton. Two hundred weight in some works, and one hundred weight in others is carried at once.

The mixture of the charges is one of the chief points in good smelting, and taxes the skill of the managers, for many classes of foreign ores are brought into our smelting works, and in some countries abroad a great variety of ores is found and smelted. In other countries the quality of the ores is tolerably uniform, and the course of working is very regular. Where new ores are received, several trials may have to be made before the working is good, and sometimes the charge is worse at the end of the time than in the beginning.

In the early stages of copper smelting, the object of the manager is less directed to any operation on the copper, to the manufacture of copper in fact, than to the manufacture of slag, for the removal of silex depends on a good silicate of iron being formed, which will freely flow out separate from the regulus. This is an essential point to bear in mind, for the slag may be pasty, and so carry off a portion of the metal, or it may be full of shots of copper and so wasteful, while the object is to get rid of the silex with as small a quantity of the valuable article copper as may be. A good clean slag is, therefore, the satisfactory test of working, and the slags are anxiously examined by manager and men.

The charge of ore is put in through the bin or hopper at the top of the furnace, and is spread over the hearth, or rather bottom, with the rabble. The slag is thrown into the furnace through a side door, in large lumps. All the doors are then luted on tight with fire-clay, and the charge is melted for about five hours, when the furnaceman starts his fire afresh.

About this time he begins the moulding of his metal beds, and his slag beds, which are formed of sand, the metal beds near the tap hole, and the slag beds before the fore-door. Any kind of common sand, dry, will do for these beds, as the moulding is rough.

Commonly about the end of five hours, the furnaceman takes off the fore-door, which is burning hot, with an iron rod. He stirs the charge through the fore-door with a long rabble down to the bottom. If the charge is all right and thoroughly melted, he puts up the door and gives ten minutes for the metal to settle down to the bottom. The door is then taken down, and the slag is skimmed off with the skimming rabble through the fore-door into the slag-beds. The slag is run over the lower bar of the door, which is above the level of the bottom. The man can see the bright level surface of the metal, and observe by the eye whether it is clear of slag. It is his object to get the molten metal free from slag, and the slag free from copper; and more particularly, as all slags found to contain more than an allowed portion of copper have to be smelted by him free of charge. These are the checks for good working.

The metal is tapped into the regulus into pigs, but not until there is enough regulus from several charges.

In this process it is sometimes necessary to add fluxes to the charge, as fluor spar, lime, shells, shelly sand, cinders, anthracite coal. Fluor spar is obtained from Cornwall, and M. Le Play estimated the consumption in South Wales at 7,800 tons yearly. At present some works use no spar, and others not more than one hundred tons yearly. Shells are not used in this country, nor are carbonaceous fluxes esteemed.

Five charges can be put through a furnace in a day when the ore is good, and sometimes six. The work goes on night and day except on Sundays. The men are paid by the ton of ore in the charges, the ton being reckoned at 22 cwt.; the rate is now about 1s. 6d. per 22 cwt., or 2s. 9d. per 33 cwt., and a man's earnings are about 28s. per week. The men are one for the day and one for the night. The men of neighbouring furnaces help each other. The consumption of coal, working from four to five charges, will be from 25 to 30 tons per week.

The stuff put into the furnace will be, say—

Copper......................................	10¼
Silica	55 to 65
Iron	34 to 39
Sulphur	7½ to 10¼

The produce is—

COARSE METAL.

Copper......................................	10¼ to 11
Iron	10¼ to 15
Sulphur	10¼ to 7

SLAG.

Silica	55 to 65
Iron	24 to 29

with a trace of antimony and tin.

The slag is a protosilicate of iron (34·62 protoxide of iron, and 65·38 of silica) with nodules of silex imbedded.

III. CALCINING POWDERED REGULUS OR COARSE METAL.

One of the old processes was to run the regulus or coarse metal not into beds, but into a basin of water or cistern, in which it was granulated. A part of Napier's improvements consisted in dispensing with this by a chemical mixture, but Mr. Alfred Trueman further improved by stamping the regulus to powder.

The powdered regulus is put into a calciner, which is the same as an ore calciner, and the general mode of treatment is the same.

The charge put in is from 3 tons to $3\frac{1}{2}$ tons, weighed out 2 cwt. at a time. The charge is put on to the roof, and so passed on to the floors. It is spread in the same way, and stirred every second hour. One charge is passed through in twenty-four hours, the calcining taking double the time of ore. At the end of the time, the regulus powder is cast into the cubs. Some sulphur is discharged in the cubs in vapour, which is passed through the cub dampers into the culvert.

The weekly consumption of coals is about seven tons. Inferior coals may be used for calcining ore or metal. Bituminous coal will do for this.

Two men are employed for the day watch, twelve hours, and two for the night. Their pay is about 18s. to 20s. per week.

About six charges are passed through in a week; the powder calcined, being a regulus of, say—

33 copper,
33 iron,
33 sulphur,

has lost the greater part of its sulphur, and acquired oxygen, forming oxide of copper and oxide of iron.

IV. MELTING CALCINED COARSE METAL.

The furnace is the same as an ore furnace.

The charge is made up to a total weight of about 52cwt. There is here an opportunity of introducing raw ore again as rich carbonates, and the following will represent a charge:—

Calcined powder	24 cwts.
Foreign raw ore	24 ,,
Refining, or roaster slag	4 ,,
Total...........	52 ,,

Another example is:—

Calcined powder	23 ,,
Foreign raw ore	24 ,,
Refining, or roaster slag......	5 ,,
Total	52 ,,

Another example is:—

Calcined powder	20 ,,
Raw carbonates	20 ,,
Refining, or roaster slag......	8 ,,
Total...........	48 ,,

Of these the charge may be made up with calcined powder and slag, and this is the case abroad, but English melters have to work up a great quantity of foreign ores, which they are thus able conveniently to introduce.

The ores in the charge are well mixed together in the ore-yard before being supplied to the men.

A charge is in about six hours, and is treated much in the same manner as in the ore furnace. The slag is skimmed in the same way, but the regulus, being more abundant, may be tapped every second charge.

The coal consumed is about four or five tons a day, or about thirty tons a week.

There is one man for the day watch, and one for the night watch. One furnace will pass through about 2,200 tons of ore, holding about 700 tons of copper.

The result is *blue* or *fine* metal and sharp slag.

The metal consists of,

Copper.........................	70 to 83
Sulphur	30 to 17

The *sharp slag* consists of:—

Protosilicate of iron, with some copper and antimony.

The slag is so called because it is bright, breaking into sharp-edged fragments. They contain no shots inside, but small shots sometimes on the outside.

V. PROCESS.—ROASTING FINE METAL.

A roasting furnace or roaster is the same as an ore furnace, but has no bin, as it is charged by the side-door. There is an airhole in each back corner, called a porthole, which leads on to the furnace floor.

The charge put in is from 3 to $3\frac{1}{2}$ tons of metal, rough weight, or enough to produce $2\frac{1}{2}$ to 3 tons of copper. The charge is in about 24 hours. Each pig of metal is put in with a paddle. The portholes are partially opened, and fire is gradually raised for the first eight hours, and the metal kept red-hot. The fire is then raised a little for another eight hours, so that the metal will sweat down. The portholes are closed and the doors luted tight, when the fires are raised and driven on until the charge is thoroughly melted on the bottom. About the nineteenth or twentieth hour the front door is taken down, and the metal is stirred with a rabble. If all appears clean, the small quantity of rich slag produced is skimmed, and if the metal is clear it is tapped, if for export, as in foreign works, into iron moulds as pimpled bar copper, but if to be carried to refined, it is tapped into beds as pigs for the next roasting.

The quantity of coal consumed is from 22 to 25 tons per week.

The men's wages are about 3s. to 3s. 6d. per watch.

VI. PROCESS.—SECOND ROASTING.

When fuel is abundant and working careful, the metal is subjected to further treatment, and sometimes to a further roasting of twelve hours.

VII. OR VIII. PROCESS.—REFINING.

The refinery furnace is the same in form as the ore surface, but is smaller, and has no bin or tapping-hole, being charged from the side door, and ladled out from the fore door.

The charge in a refinery furnace will vary from five to six tons of pimple copper in pigs. One charge is put in each day. The metal is melted fiercely for several hours and skimmed for the slight slag. Air is let in from the side door till the copper begins to "work" or coil up, and when the refinery man, with a little rabble, moves or flaps the surface a little. The "working" is continued for two hours, when the copper is seen to "blister" or rise in black scales, having become blistered copper. The man keeps the side door down, and lets the copper solidify according to circumstances, 2, 3, 5, 6, or 7 hours. The doors are then luted, and the metal melted afresh for 3 or 4 hours.

The head refiner now takes charge of the operations, and proceeds to take a small test in a ladle, which is worked into an ingot and tried on the anvil. If found fit, lead is put into the surface, about 16lbs. to 6 tons of copper, and some charcoal is spread over the surface of the copper, and, further, the copper is stirred with a stout pole. He continues to test the copper, and as he finds the "pitch" or grain so he backens or forwards the operation, and gives air or poles more.

The refined copper is cast into ingots, tiles, or wire bars, according to the demand. It is sometimes refined a second time, if "best select" is to be produced.

In making bar copper for sale on a large scale, it is a practice in some countries to mark the bar with the maker's name in the casting, and likewise the number of the charge, so that a quantity may be dealt with as of one make. Sometimes the number is punched.

Bar copper is sampled for sale according to a plan practised by Mr. Hussey Vivian, by drilling a hole, of from one-eighth to half an inch diameter, half-way through the bar from the top, and another half-way through from the bottom, but not so as to meet, as they make two half-sections, and thus afford a better average section. The drill is worked in a frame. The filings so obtained from each bar drilled are divided into four parts, a, b, c, and d; a and d going to the buyer, and b and c, as samples, to the seller, and from the total samples is taken, alternately, a check sample, under the seals of the buyer and seller.

The drilling is rapidly done. The quantity taken is about one dram for each cwt., where the bars are of one charge or smelting, so that the total shall not be less than 240 drams or one pound weight, all the drillings are well mixed together. The drilling from 4 cwt. would be 240 drachms and from 16 tons of the same charge about 320 drachms.

The following is an analysis of select copper:—

Copper	99.80	to	99.85
Iron	0.10	to	0.15
Lead, Antimony	nil.		nil.
Oxygen, of no consequence.			
Silver	do.		do.

Select copper, as follows, will not sell:—

Copper	99.85
Iron	0.10
Antimony	0.01

or, even a trace of antimony.

The following is an analysis of the very best cake copper:—

Copper	99.60	to	99.70
Iron	0.10	to	0.15
Lead	0.10	to	0.15
Antimony	0.04	to	0.06
Silver (objectionable.)			

The average consumption of coals to a ton of copper is about 10 to 15 tons per ton of pure copper, depending on the per centage of the ores, and the goodness of the coal.

Mr. E. J. Cole, Secretary of the Alten Copper Company at Norway, and the Copiapo Company of Chile, who has been long connected with the smelting interest, has been kind enough to give me for this paper some particulars of the working of copper in Norway:—

"The following will give you some idea of the business at the Alten Copper Works:—

"The quantity of ore reduced in 1857 was 1,899 tons, $\frac{822}{1000}$, producing 123 tons of fine copper, the average quality being $6\frac{47}{100}$.

1874 tons, 036 ore, 402 tons, 600 metal slags, 19 tons, 000 sweepings,	Were reduced in the ore furnaces, and consumed 1464 tons of coal.
418 tons regulus, 25·786 tons ore, 57·820 tons refinery & roaster slag, 73·800 tons furnace bottoms,	Were reduced in the metal furnace, and consumed 224½ tons of coal.

212·500 tons white metal were roasted, and consumed 185 tons of coal.

128·000 tons black copper were refined, and consumed 34 tons of coal.

"You will thus see the process of reducing the ore to fine copper, and the consumption of coal in each reduction.

"The cost of coal, as you are aware, delivered at Alten, is about 12s. per ton. Some time ago we were able to secure freights very low, and we then had the coal delivered as low as 8s. to 9s. per ton. The great expense of reducing ore is in the first process, where the largest quantity of coal is consumed, and when the ore is reduced to regulus; the after processes are comparatively easy.

"The cost of reduction in 1857 was, per ton of ore, 28s.; per ton of copper, £21 12s.

"At Alten we, fortunately, have various descriptions of mineral, and are able to make good fusible mixtures; hence we obtain, as we consider, very satisfactory results, and our copper ranks equal to the best selected, and a good market is always obtained."

FURNACES.

A double-bedded single calciner, 30 feet long over casings, exclusive of grate, and 14 feet wide, will require, besides the bricks of the stack or culvert, about 50,000 bricks, fire and inferior qualities, but in which old bricks can be worked up; 2 tons of best fire clay and 8 tons of common fire clay; 80 bushels of lime; 120 bushels of sand; a small quantity of fire sand; about 40 tons of stone for foundations (but this depends on circumstances); of sundry clay pottery, 200 or 300 soaps and as many splits; 20 slabs and 20 bearers. The wages will be, mason 156 days, boy 156 days, labourer 48 days, besides head masons and smith for the smiths' work. The time in building will be about 20 days, exclusive of odd jobs in finishing off and setting the calciner going.

The iron work for such a calciner, consisting of cramps, studs, door frames, plates, bearing plates, sleepers, teasing hole, sliding frames, and slides, will vary according to the mode of construction adopted in the several works. The smiths' time in fitting would be seven days, and a labourer seven days.

A single double-bedded calciner will take about 24,000 fire bricks and 1,200 red bricks, 2 tons of best fire clay, 8 tons of common clay, and other materials as before. The labour will be less, both of masons and smiths, in proportion to the difference of materials.

The grate will be about the same as the grate of a furnace of like dimensions.

The stack will be the same as for other furnaces and its cost will be according to the system of stacks adopted.

Furnaces are worked with stacks according to various plans depending on the circumstances of the works, or on the fancy of the owner, manager, or mason. Some work the furnaces with a stack for each pair of furnaces, and some have all the flues brought by an underground culvert to one central stack. In the Cwm Avon Copper Works of the Copper Miners' Co. of England there is not one stack on the premises, but all the furnaces communicate with one common culvert, which is carried for a distance of about a mile and a quarter up the side of a mountain, whence the smoke is carried up a stack forty feet high on the top, forming a conspicuous sight for miles around, and with a draft strong enough to carry a man up into the air. This volcano can be seen for a considerable distance on a clear night, and on a fine day from as far as Tenby. A man took a contract for clearing out this culvert on condition of having the culvert stuff for his remuneration, presuming that it contained the usual average of copper throughout, as a considerable quantity of copper goes up the stack. The contractor, however, made an unfortunate bargain, and abandoned his contract, as the chief stuff was sulphur and arsenic.

In some works a central stack and single stacks may likewise be found, but the balance of experience is not in favour of either system so as to secure its decided adoption. The objection to a central stack and long culvert is, that the draft of individual furnaces is sometimes interfered with, and therefore stacks for each furnace are by some preferred. The advantages claimed for the central stack and culvert, are, that an inferior draft is obtained and that the copper passing out of the furnace in fume is saved; it is certainly true, that in a single stack but little stuff is saved, whereas in a culvert there is always stuff containing copper which can be smelted.

An objection taken to a central stack is, that it may interfere with the working in case of repairs, but if there be one line of culvert running between the furnaces, and at each end of the culvert a high stack, then, by means of a brick partition set up in the culvert, the number of furnaces to each stack may from time to time be variously apportioned, particularly during the repair of end furnaces, then all the remaining furnaces may be put on one stack. The draft of a central stack will be affected by the greater or less number of furnaces working on it, and this is felt to be an inconvenience by the smelters.

One circumstance that will affect the height of stacks is the situation of the works. A number of high stacks belching forth sulphur and arsenic night and day destroy the vegetation of the neighbouring fields wherever the pestilent breath touches, the field being stripped of herbage,

as if by locusts, and brought to the appearance of a bed of shingle. Copper works, are however, mostly situated in waste districts.

Much attention has been given to this evil, and the great waste of sulphur and other substances carried off in smoke, and many plans have been proposed for their recovery, but as yet no particular result has been obtained. There is no question that the loss is very considerable, forming part of that great waste of residuary matter which meets with too little attention in England.

A stack 50 feet high, and with an inside lining of 50 feet and outside lining of 30 feet, will, exclusive of foundations, require 3,100 fire bricks for the inside lining, and 2,500 common red bricks for the outside, $2\frac{1}{2}$ tons of common fire clay to be used inside, up to a height of 30 feet, 20 bushels of lime, 40 bushels of sand, and a little fire-sand for mixing with the clay. The wages will be, mason 24 days, boy 24 days, and labourer 21 days, besides superintendence; the time in building will be 9 days. All this is exclusive of foundations, which vary according to situation.

Such a stack is rodded or cramped with iron rods, for better security against the action of the furnace flames passing through, and there will be used 530 feet—$\frac{5}{8} \times \frac{5}{8}$ square, for rods, 400 feet $1\frac{1}{4} \times \frac{1}{4}$ flat for cramps, and 200 feet 3 inches by $\frac{1}{4}$ flat for cramps, beside a quarter of a hundred weight for wedges. The smith and his labourer's time will be 9 days.

The cost of a furnace will vary according to its purpose, its situation and its dimensions. The following is for a large reverberatory furnace:—Outside dimensions over casings 22 feet 6 inches length, 15 feet width, add for grate 6 feet 2 in length by 8 feet 8 in width. Height of casings, from the floor at the grate end, 5 feet 11 inches, at the fore part 4 feet 6 inches. Inside dimensions of furnace 14 feet length by 11 feet width. Thickness of inner and outer casings at the side, 2 feet, of jambs and sides of grate 2 feet 1 inch, of back of grate 9 inches.

Such a furnace would require about 8,500 fire bricks and 3,500 common red bricks, and about 3,000 old bricks might be used up; of fire clay, best, 4 tons, and common 7 tons; of lime, 80 bushels; of sand, 120 bushels, and a small quantity of fire sand; of pottery, 200 soaps or closers; 200 splits, 8 slabs of various dimensions, and twelve bearers, whole or in halves. The wages will be, mason 60 days, boy 60 days, labourer 60 days, exclusive of superintendence. Such a furnace can be built in ten days, exclusive of odd jobs and finishing off.

The iron work for securing the furnace will be as follows:—*Wrought iron*, 260 ft. 1 $\times$ 1 square bar, 100 ft. $\frac{1}{8} \times \frac{1}{8}$ square bar, 100 ft. $\frac{3}{4} \times \frac{3}{4}$ square bar, 26 ft. $1\frac{1}{2} \times \frac{5}{8}$ flat, 100 ft. $1\frac{1}{4} \times \frac{1}{4}$ flat, 80 ft. 3 in. $\times \frac{1}{4}$ inch flat; 8 ft. $1\frac{1}{2} \times 1\frac{1}{2}$ square bar; 4 studs 9 ft. long $\times$ 3 $\times$ 3 in.; 2 studs 5ft. 6 $\times$ 3 in. $\times$ 3 in; piece of wrought iron 5 ft. 3 in. $\times$ 3 in.; teazing pot; stuff for wedges. *Cast iron*:—14 studs 6 $\frac{3}{4}$ ft. $\times$ 3 in. $\times$ 3 in.; 7 studs 6 ft. 3 in. $\times$ 3 in. $\times$ 3 in.; 12 studs $5\frac{1}{2}$ ft. $\times$ 3 in. $\times$ 3 in.; 1 bearing plate 6 ft. $\times$ 9 in. $\times$ 2 in.; 3 sleepers 6 ft. 4 in. $\times$ $4\frac{1}{2}$ in. $\times$ $2\frac{1}{2}$ in.; 1 bearing plate 7 ft. $\times$ 9 in. $\times$ 2 in. 1 concave or convex plate $7\frac{1}{2}$ ft. $\times$ 30, $\times$ $3\frac{1}{2}$ and $1\frac{1}{2}$ in.; 2 fore-plates, 5 ft. $\times$ 20 in. $\times$ 3 and $1\frac{1}{2}$ inches; 2 skimming plates, 3 ft. $\times$ 7 in. $\times$ 3 in., made in three plates each. The wages will be—smith, for fitting, 14 days, and his labourer 14 days. The particulars and dimensions of this ironwork will vary according to the fancy of each manager.

In some of the latter works the furnaces are still found cased in a jacket of thick iron slabs, secured by the studs, but it is not a good plan, as defects in the brick work cannot be so well seen, and airholes may thereby escape notice, nor is the furnace stronger, cheaper, or more durable.

A furnace exposed to the intense heat of copper smelting is always in process of consumption, and its repairs are continual. The outside casings will last five years, which is about the longest life, but the inner portions are perpetually burnt up. A grate will last at the least 8 weeks, at the longest 13 weeks, so that there will be 6 grates in a year. The inside of an ore furnace with repairs will last from eighteen months to two years, but of a metal furnace only from nine to twelve months.

In a subject so extensive as this omissions are more likely to be noticed than what is described, but the commercial portion of the transactions is both important and considerable, and would require a paper by itself; and it is the more deserving of notice because the profits of the copper business depend more on good trading than on manufacturing cleverness.

DISCUSSION.

Mr. Charles Low wished to make a few remarks upon the very interesting paper that had just been read. The subject of copper smelting was a most important one, as it embraced one of our largest manufacturing interests, and it was a manufacture that had had fewer improvements made in it since its first commencement than any other in this progressive country. In fact, it might be said that since its first introduction little or no permanent improvement had been effected. This arose principally from two causes, the first of which was that the copper smelting business was a complete monopoly in the hands of about ten individuals, who entirely ruled the trade as regarded the prices to be paid for copper ores and other matters, and who were also extremely adverse to any kind of improvement being introduced into the manufacture of copper, and would, moreover, throw every possible impediment in the way of such being carried out. The next difficulty was, that although most important discoveries might be made in the laboratory, it was frequently the case that it would not be possible to carry them out on a large scale on account of the expense attending the process, or the impossibility of obtaining the use of works to make the trials. It must be also borne in mind that the material to be operated upon was of great bulk, the matrix of the ore being so out of all proportion, when compared to the quantity of metallic copper produced. The average produce of copper ores, produced from English mines, did not exceed $6\frac{1}{2}$ per cent., and when the produce of the foreign copper ores imported into this country was added to it, the produce of the whole would not quite average 10 per cent.; so that, for every ton of fine copper produced, at least ten tons of ore must be smelted. From this it was obvious that, to treat such a vast bulk of material the cheapest possible process must be adopted. From a description of the present process of copper smelting, in the paper just read, it appeared to be as nearly as possible the same as was carried on at one of the earliest copper-smelting works, erected at Bristol, upwards of 100 years ago. The ores were submitted to from seven to ten different processes, from the time they were first placed in the calcining furnace until they were produced from the refinery in the shape of fine copper, and this occupied ten days. Now to carry out this long process it was obvious that the cost of coal, labour, wear and tear of furnace, and other matters, was very great, and any improvement that would tend to lessen this was most important. Some attempts had been made for the reduction of copper ore by what was called the wet method, by means of acids, but this had failed, owing to the bulk of materials to operate upon being so great, and rendering the process too expensive. Having had much experience in metallurgy, and particularly copper smelting, he (Mr. Low) was induced to go into the matter very closely, and, after first ascertaining the exact effect required to be produced upon copper ores by submitting them to the present protracted operations, then to ascertain whether some other method could not be used by means of the application of proper fluxes to effect the same object more economically. In the first place, what was the effect in-

tended to be produced by the present method of smelting? It was simply to desulphurise the ores and deprive them of the iron contained therein by oxidation. This was at present effected simply by heat, applied during a series of long and expensive processes. After much research, he (Mr. Low) had discovered a plan of operation, which obviated these difficulties, and which he patented. The process was as follows :—The ore was first calcined in the ordinary mode, and then introduced, likewise in the ordinary way, into a reverberatory smelting furnace and smelted, and, after skimming off the slags, was run out into sand-beds, not into water, as just mentioned in the paper read, which in his (Mr. Low's) opinion was useless. The metal thus produced was a regulus. It was then placed in another reverberatory furnace, which was constructed with orifices on each side the bridge of the furnace to admit a current of air; this improvement being also patented. The current of air passed between the flame and the surface of the melted metal, and impinged on the latter, greatly assisting the operation. The flux, consisting of certain proportions of manganese, plumbago, carbon, and saltpetre, was then introduced, and the effect produced was that the iron, sulphur, and other extraneous substances were oxidised; the copper was set free and brought into a metallic state, and at the end of twelve hours was fit for the refinery, so that by this process the finest copper could be produced in 36 hours which, by the ordinary process, could not be effected in less than ten days. The saving of coal, labour, and other matters would be obvious to all. This process was not a mere theory, but had been carried on by him upon a very large scale, and many thousand tons of fine copper made by it. In conjunction with others, he had erected large copper works near Swansea, and fully carried out the process, and it was found that the copper produced was of very fine quality, and sold in the market £2 or £3 per ton higher than the finest copper produced elsewhere; moreover, the cost of smelting by this process was 50 per cent. less than by the ordinary method. This success naturally brought upon him the opposition of the monopolists, and every attempt was made to drive himself and partners out of the trade, and, of course, at last with success. The price of copper was lowered to an unprecedented extent, and the price of ore raised, so that it was quite impossible to continue their operations except at a loss; and, in order to avoid losing the whole of the capital embarked, they determined upon discontinuing operations, but not until the success of the process was completely established. He mentioned the fact of the success of this improvement principally for the purpose of showing how much might be done towards a cheap production of copper, and he believed it to be but a small step towards further chemical discoveries, which would effect a far greater saving. The position in which one of our most important industrial commercial interests was placed by the existence of such a monopoly was, indeed, to be regretted. Our mining interests were, in fact, at the mercy of certain parties to give any price they might think proper for the ore produced, and, according to a calculation he had just made, he found that the profit made by the copper smelter upon every ton of fine copper produced was £40, after paying all charges, and as the quantity of fine copper produced in this country exceeded 30,000 tons per annum, they might calculate the princely revenue that accrued to the monopoly. But there was a remedy that could easily be adopted to meet the difficulty. Let a few influential owners of mines combine to smelt their own ore by a cheap process, either in Cornwall or elsewhere, and the monopoly would very soon be at an end. The smelter would still have ample profits, and the miner receive a proper and just remuneration for his outlay of capital and perseverance.

Mr. J. Arthur Phillips, having been requested by the Chairman to give some information relative to the various humid processes now employed for treating copper ores, described the method made use of at Riotinto and various other localities, for the treatment of the poorer sulphides of copper, by cementation. Mr. Phillips subsequently described the process of Mr. Rhodins, of Linz, on the Rhine, by which the copper is extracted by the aid of sulphuric acid, derived from the sulphur of the ores themselves. The processes of Mr. Sinding, for the precipitation of copper from its solutions by means of sulphuretted hydrogen, obtained by the decomposition of the gases, yielded by the dry distillation of fuel when passed through pyrites heated to redness, were also given, as well as the method of treating the cupreous sandstones of Twista, in the Waldeck, by hydrochloric acid, and subsequent precipitation of iron. Mr. Phillips also described, and made some observations relative to, the copper deposits of Tennessee and Virginia, United States of America, which, he was of opinion, were the result of decompositions of a secondary nature, and which were, in all probability, still actively progressing.

Mr. Murchison was sure he expressed the opinion of all present when he said that Mr. Hyde Clarke had shown himself to be completely master of the subject which he had so ably brought forward that evening. There was one point in the paper which had particularly struck him (Mr. Murchison), namely, that, "At present copper smelting is a routine work, pursued on much the same plan as of old, and on the same general system in most works, followed out as a mechanical practice rather than as a scientific occupation." This statement had been fully confirmed by a previous speaker (Mr. Low), who was practically engaged in the trade. He (Mr. Murchison) recollected reading an article in one of the daily newspapers, a few years ago, with reference to free trade, in which the writer expressed an opinion that, in a very short time, a protectionist would be so rare a creature, that his proper residence would be the British Museum. The writer, however, had evidently forgotten the copper smelter, in as much as they found that the process now in practice for copper smelting was the same as that adopted at its origin 150 years ago; so that, whilst all other businesses and professions had undergone a complete revolution, and whilst the advancement of science had enabled all manufacturers, except the copper manufacturer, to progress, yet the copper smelter adhered to his antiquated notions, and preferred the good olden time. He believed that it was in the year 1708, when the first piece of copper was manufactured in Cornwall, by Sir Talbot Clerke; and many other attempts were made to carry on the smelting business there; but it was not until 1720, or 1726, that copper mining in Cornwall enabled the smelting trade to assume any degree of importance. In the year 1726, the total produce of the copper mines of Cornwall was about 5,000 tons. In 1750, it increased to about 10,000 tons; and in 1754, the first smelting works were erected at Camborne, in Cornwall, which were afterwards removed to Hayle, to be nearer the port of shipment and nearer also to the fuel. An opinion had been expressed by Mr. Low, that if the copper miners of Cornwall adopted the plan of smelting at the mines they would find it most lucrative. He believed that as much as 100 years ago that plan was attempted by some of the principal copper miners of Cornwall, who not only endeavoured to calcine the poorer ores, but also to bring the ore into a state of regulus; but, such was the amount of opposition offered, that the project was abandoned—for the reason given by the smelters that the two processes performed upon the ore by the miners interfered considerably with the large profits made by the smelters. From Cornwall the smelting trade was carried to Bristol, but it was soon found that the cost of the double freight of the raw produce to and from Bristol, added to the cost of fuel from Wales, was a commercial mistake, which led to the trade being carried to Swansea and Neath. In later years the copper mines of Cornwall had rapidly increased, until, at the present time, as much as 150,000 tons of copper ore were raised from those

mines alone every year. He would make a passing allusion to one remark of Mr. Hyde Clarke, who seemed to entertain some apprehension that the introduction of the rich copper ores of Australia and other countries would produce a sensible effect upon the working of the copper mines of England. He found the facts of the case to be, that, although there had been an increase in the importations of foreign copper, there had been a large decrease in the production of British copper, and that the increase in the importation of foreign copper ore was not proportionate to the decrease in the production of copper from the British mines. That, he considered was not owing to the circumstance of the richer foreign ores preventing the British miners from working their poorer ores, but the average richness of the British copper ores had decreased, and the fact was that the produce of the British copper mines had decreased in proportion to the extent of the importations of foreign copper. He was in hopes that several of the practical men whom he saw present would have favoured the meeting with the results of their own experience in those matters; but as a member of the Society, of some rather long standing, he hoped he should not be considered out of order if he proposed a vote of thanks to Mr. Hyde Clarke, for the manner in which he had brought this subject before the Society. It was now something like 15 years since he had the honour of becoming a member of this very useful, and, he might add, illustrious Society. He was quite aware that practical papers were not those which always attracted the greatest attention; yet, although they appeared to be composed of dry materials, if those who took an interest in them would study them in detail in the Society's *Journal*, their importance would be appreciated. Having alluded to this Society and the wide sphere which it now occupied, not only in this country, but, he might say, in its varied ramifications throughout the different quarters of the globe, there was one thing in which he thought, perhaps, they had been somewhat remiss—that was that they had not been sufficiently prominent in offering rewards for improvements in the process of copper smelting.

Mr. P. L. Simmonds, being called upon by the Chairman, stated that he found he could add very little to the exceedingly practical and useful paper submitted to the Society by Mr. Clarke. The subject was one which required careful study to master the mechanical and business details so elaborately given. Mr. Clarke, from his business connections, and his ready grasp and comprehension of any matter brought before him, had been able to furnish to the Society, and through the Society to practical men at home and abroad, a large amount of very useful and instructive information not always accessible to the public. Mr. Clarke had observed that the supply or production of copper, home and foreign, did not come within the scope of his inquiry, but it was desirable, perhaps, to form an idea of the comparative value of this important metal. From the private purchases of home and foreign copper it was difficult, as Mr. Hunt had observed, to form a correct estimate. But our imports of foreign ore and regulus had been increasing of late years; the imports last year having been 75,832 tons of ore, and 19,262 tons of regulus, besides 7,000 or 8,000 tons of old copper and other forms; the largest quantity arriving from Chile, 21,385 tons, the next from Cuba, 16,352 tons, and 13,000 from Spain, besides small quantities of a few thousand tons from other quarters. Upwards of 8,000 tons were received from our Australian possessions, and 3,382 from Southern Africa. Our exports of wrought copper now approximated in value to three million sterling, and had been steadily increasing. There was one feature of the subject which could not, perhaps, be well alluded to by Mr. Clarke, but had been previously adverted to by the first speaker, and that was the injurious influence of the copper smelting monopoly on the projects of improvement and extension of the trade. These close monopolies had been found highly injurious to the advance of various other trades, and were gradually being abolished, in accordance with the more liberal policy of the day. Why our metal trade should alone be cramped by these exclusive and arbitrary influences, when so sweeping a censure was levelled at great monopolising companies, he could not conceive. He, therefore, had hoped to hear some practical men, of whom there were so many present, speak to this point, and suggest plans or proposals to remedy this gigantic abuse, by which the copper miners of Cornwall had suffered so severely from the fluctuations of the trade—for within the last year copper had fallen £26 per ton. While the metal trades were all open trades, they were at the same time all monopolies, and it would be well to consider how the interests of our mines were affected and compromised by the unfair influences thus exercised, which retarded improvement, and naturally influenced prices.—Mr. Simmonds subsequently handed in to the Secretary the following statistics, as bearing upon the subject of the copper trade.

Exports of copper from South Australia :—

	Metal.	Ore.
1853	24,303 cwt.	3766½ cwt.
1854	8,119 ,,	3247½ ,,
1855	12,255 ,,	4039 ,,
1856	44,980 ,,	9468 ,,

Copper ore exported from Cuba :—

1851	432,882 cwt.
1852	381,470 ,,
1853	345,080 ,,
1854	549,553 ,,
1855	372,608 ,,

Exports of copper of all kinds in the last three years, with the declared value :—

	Quantity.	Value.
1855	17,498 tons	£2,110,916
1856	22,863 ,,	2,648,259
1857	25,241 ,,	2,855,831

Mr. John Bethell said he could testify to the fact that the copper monopoly in this country had been the means of retarding improvements in the smelting and manufacture of copper. A few years ago, a foreign gentleman came to this country with a view of introducing a process of smelting different to what was carried on here. He (Mr. Bethell) gave what assistance he could in carrying out the project, but the great difficulty they had to contend with was that they could not get a supply of ore. The monopoly of the English copper smelters was such that parties not connected with the Copper Smelters' Association of Cornwall and Devon could not procure a supply of ore; and although they might purchase foreign ores, they could not obtain English ores to mix with them, owing to the monopoly which prevailed in that trade.

The Chairman said, in the absence of any further observations on this subject, it was his pleasing duty to put to the meeting the proposition of Mr. Murchison, that they should return their best thanks to Mr. Hyde Clarke, for his very able and interesting paper. With the permission of the meeting, he (the chairman) would say a very few words upon the important subject which had been presented to them. They could, none of them, be insensible to the gigantic development that had taken place in the metal manufactures of this country, and no one could fail to see that this had been the growth of the last half century, although it had been less in copper than in iron; in both branches of manufacture, however, the advance had been enormous in a very short period of time. The industrial and economical interests involved in the production of copper could not be exaggerated. It was therefore of the utmost importance that practical information should be given in so useful a manner as it had been that evening upon the various processes whereby copper could be best manipulated, and whereby that

extraordinary monopoly which had been alluded to might be, sooner or later, put an end to; for he felt, that when light was thrown upon a subject of such deep and pressing interest beneficial results must accrue. He recollected that the smelting of copper was introduced into Monmouthshire half-a-century ago, and works were erected at Risca, a few miles from Newport; but they were stopped, owing to the monopoly in the trade. At that time, in order to ensure the supply being below the demand, a ballot took place between the smelters as to which works should be closed, and the works to which he alluded were those upon which the lot fell, and from that time to the present those works, which were most fortunately situated in the centre of the coal fields, had stopped all operations. It was obvious that if they brought to bear improved manipulation, and improved chemical and mechanical processes, in the conversion of ore into metal, they necessarily limited the power of monopoly by decreasing the amount of capital required to be employed in carrying on those operations, and to that extent they increased the ability to compete with those who at present held the field against the public. Although he was not practically acquainted with this subject, he was, nevertheless, fully alive to the commercial and industrial importance of the question before them. He trusted that this paper, and the discussion which had followed it, would lead to further inquiry. In conclusion, he would put to the meeting the resolution proposed by Mr. Murchison, which otherwise he would himself have brought forward, namely, a cordial vote of thanks to Mr. Hyde Clarke for his paper.

A vote of thanks was then passed to Mr. HYDE CLARKE, who, in acknowledging the compliment, said that in bringing forward a subject of a practical nature, the author of it had necessarily to run the gauntlet of criticism. On the present occasion they were favoured with the attendance of gentlemen who were not simply connected with the trade, but who had many of them introduced considerable improvements and exercised an important influence upon it, so that the test had been a severe one. With regard to what had fallen from Mr. Low, he (Mr. Hyde Clarke) could confirm his statement as to the general principles involved in the process he had described, which he could testify had been carried out with great success in o her cases; this confirmed the principle laid down by him, that copper ore could be reduced in a shorter space of time than by the methods ordinarily employed, by the addition of carbonaceous flux, although it was considered by some to deteriorate the quality of the copper. He had, however, seen specimens produced by Mr. Low's process, which were as good as could be desired. The Chairman had called attention to the growth of the metal trade in this country. That was a branch of the subject into which it was not his province to enter that evening. The growth of that interest was the result of unrestricted competition, and the stationary condition of the one branch which had been then under discussion was, in his opinion, to be attributed to the monopoly that existed in it. So far as the treatment of ores was concerned, they were nearly all subjects of monopoly in this country. No one knew better than Mr. Murchison the difficulties that had to be contended with in the metal markets, and these difficulties applied to ores other than copper. They existed with regard to tin, spelter, lead, and silver, and also the less important metals, nickel and cobalt, all of which were held by three or four influential houses; and large portions of copper ore containing gold and silver were lost to commerce from this state of the trade. With regard to Bristol, he had no intention to depreciate the importance of the smelting works there; but in the present state of the trade there was no doubt they were of less importance than the enormous works in South Wales. Mr. Phillips had misunderstood him as to the future of copper mining in this country. That gentleman had brought forward some valuable remarks as to the average per centage of the copper ores of England. So far from thinking this a proof of decline, they must regard it as a proof of the improvement which had taken place both in the mining and manufacturing operations; that instead of being restricted to the working of ores yielding 20 per cent. of copper, as was the case in some other countries, they could bring ores of much lower figure into the market with a profit even, as had been stated by Mr. Phillips, as low as three-quarter per cent of metal, for they could now be profitably reduced.

The Paper was illustrated with specimens lent by Dr. Percy, Government School of Mines; Mr. Gilbertson, Managing Assistant of the Corporation of the Governor and Company of the Copper Miners of England, illustrating the whole process of smelting; Mr. E. J. Cole, a like collection from the Alten Works; Mr. W. Rowley, malachite and peacock ore; Mr. T. Hancock, Secretary to the Rhine Copper Company, specimens of ore, some of 70 to 80 per cent.; Messrs. Phillips and Darlington, Lake Superior Copper; Professor Tennant, muriate of copper from Chile; pure copper with native silver from Lake Superior; native silver with native copper from the same place; and remarkable specimens from Cornwall and South Australia; and with drawings on a large scale by Mr. Hyde Clarke.

The Secretary announced that, on Wednesday evening next, the 8th of December, a Paper, by Mr. P. A. Halkett, "On Guideway Agriculture; being a System enabling all the Operations of the Farm to be performed by Steam Power," would be read. On this evening W. Fothergill Cooke, Esq., will preside.

THE ROYAL SOCIETY.

The anniversary meeting of the Royal Society was held on the 30th November, at Burlington-house, on which occasion Lord Wrottesley delivered his annual address, reviewing the progress of science during the past year. The medals were then awarded as follows:—The Copley Medal, to Sir Charles Lyell, for his various researches and writings, by which he has contributed to the advancement of geology; a Royal Medal to Mr. Albany Hancock, for his various researches on the anatomy of the mollusca; and the Second Royal Medal to Mr. William Lassell, for his various astronomical discoveries and researches; and the Rumford Medal to Professor Jamin, of Paris, for his various experimental researches on light. The election of new council and council then took place. Sir Benjamin Brodie, Bart., was elected president.

ON THE ELASTIC FORCE OF THE GASEOUS PRODUCTS OF COMBUSTION.

BY HENRY MAXWELL LEFROY (WEST AUSTRALIA).

The fact that the elastic force which belongs to the caloric contained in 1lb. of good coal is equal to the raising a weight of not less than 6,000,000lbs. through a space of one foot perpendicularly to the horizon, has been established by the investigations of Sir H. de la Beche, of Mr. Joule, and other physicists; nevertheless 1,000,000 lbs. raised one foot high for every lb. of fuel consumed, is the greatest duty actually obtained in the best steam engines hitherto constructed.

Such a vast disproportion between the amount of mechanical force theoretically due to the quantity of fuel consumed and that which is actually obtained in the best engines, certainly appears to indicate that some radical defect is yet retained in the organic constitution of this invaluable auxiliary of human industry, notwithstanding the practical perfection to which (abstracting such supposed organic defect) the unceasing labour during more than the past hundred years, of tens of thousands of the most skilful mechanics and of many hundreds of the votaries of pure physical science, must undoubtedly have brought it.

Although unknown as a skilful mechanic or votary of physical science, yet, having reflected much on this subject since 1853, when I first printed a short paper upon it, I beg to suggest the possibility, nay, the great probability that this hitherto ignored organic defect consists entirely in the rejection or non-use of the elastic force of the gases into which the fuel is decomposed by combustion and of all that portion of the caloric developed by that combustion which the time occupied in the transmission of the gases through the tubes of the boiler does not permit to pass through the material of those tubes into the water, and which must consequently be discharged into the atmosphere, partly latent, partly sensible in combination with those gases.

If this supposition be correct, the great desideratum will appear to be such a construction of the boiler and furnaces of the steam engine as will permit the whole of the gases into which the fuel is decomposed by combustion, together with the whole of the caloric developed by this combustion, to pass bodily out of the furnace into the water, and through this latter into the power cylinders; and to effect this is the peculiar object of the boiler and furnaces represented in the engraving.

The *à priori* improbability that more than a very small fraction of the total caloric developed in the furnace of a steam engine as at present constructed, can be transmitted through the metal plates of the boiler into the water within, must, I think, be evident to any person who carefully considers the molecular constitution of a plate of metal, and what is known of the physical nature of heat; and so far the recondite deductions of the physical philosopher, as to one of the most inscrutable of physical phenomena, accord well with the conceptions of sound common sense.

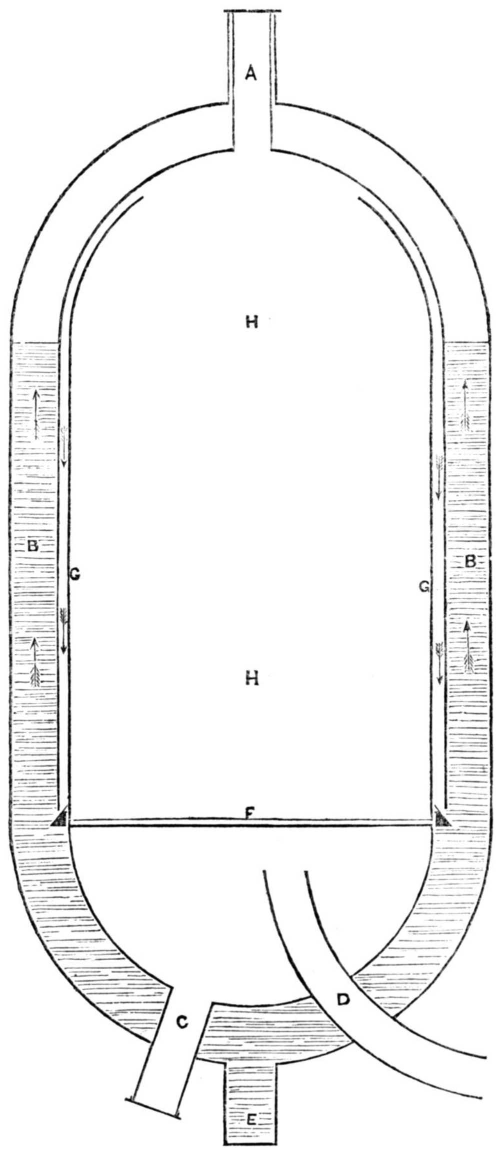
The ingenuity of engine makers has long been exerted in the endeavour to increase the ratio of the portion of boiler surface directly acted on by the fire to the volume of the boiler and the quantity of the fuel consumed; but I am not aware that a suggestion to save the whole of the caloric, which in the present construction of the steam engine necessarily is drafted through the chimney into the atmosphere, by forcing bodily into the water the whole of the gaseous products of the combustion of the fuel, has ever before been made.

An excess of pressure in the surface over that in the boiler being the means proposed to be employed for forcing the products of combustion out of the furnace into the boiler, which, it will be seen by reference to the engraving, entirely encloses it, air must be forced on to the surface by artificial means, and the combustion take place under a pressure exceeding that of the atmosphere.

I believe it will be admitted, by all who have sufficiently studied this branch of physical science, that the elastic force or quantity of caloric developed by the combustion of a given quantity of fuel, is not constant for all atmospheric pressures under which combustion can take place, but varies with some function (not exactly known, but probably, for *practicable pressures*, not differing much from the third root of its second power) of the pressure, whence a further great economy of fuel may be expected to result from the simple fact that its combustion, in the construction proposed, will take place under a high pressure, probably that of 10 to 15 atmospheres.

It must be borne in mind that the whole of the mechanical force expended in condensing the air supplied to support the combustion in the proposed form of engine, less the part consumed in overcoming the friction

A Vertical and Diametral Section of the Proposed Boiler and Furnace.



A. Pipe for supply of fuel to furnace.
B. Boiler.
C. Pipe for discharge of ashes from the furnace.
D. Pipe to supply condensed air to the furnace.
E. Pipe for discharge of lime and other impurities from boiler.
F. Fire bar.
G. Cylindrical shell for the passage of the products of combustion.
H. Furnace.

and *vis inertiæ* of the machinery employed in the operation (the whole of such condensed air passing either in an altered or unaltered state into the power cylinders) is really returned to the engine in those cylinders, and therefore it would be erroneous to consider the mechanical force so expended as a deduction from the net effective power of the engine.

Therefore, the advantages attributable to the proposed construction of the furnaces and boilers of steam-engines may be stated as follows:—

1st. The development of an absolutely larger quantity of elastic force, by conducting the combustion under a pressure of several atmospheres, than will be developed when the combustion takes place in the open air.

2nd. The conservation and utilization of the whole of the caloric actually developed, by so conducting the combustion as to pass the entire products of combustion, whether ponderable or imponderable, bodily into the water, and through the water into the power cylinders, whereas, under the existing system, the entire of the ponderable, and probably five-sixths of the imponderable products of combustion are discharged through the funnel into the atmosphere.

3rd. The diminished volume referably to power generated and consequent economy of space (so important on board of ships), of prime cost, and of subsequent wear and tear of both boilers and furnaces. A further economy will result from no part whatever of the boiler surface being exposed to the direct action of the fire, or to a destructive temperature, whilst the furnace, which alone is subjected to a very high temperature, is not subjected to any distending pressure, or rather the pressure in the furnace will exceed that in the enveloping boiler, only by that small quantity, say 1lb. to the inch, which may correspond to the most convenient velocity of motion of the gaseous products of combustion out of the former into the latter. This diminished volume, weight, and cost of the steam engine will be attended with peculiar and especial advantages in railway locomotion, and in the application of the steam engine to innumerable purposes, both of rural and urban industry, of the economy of which the easy portability of the engine is the most essential condition.

4th. The less exposure of all classes employed in the furnace and engine rooms to the injurious effects of intense heat.

5th. The entire supersession of the funnel or chimney.

Probably an experienced engine maker will readily discern other practical advantages of a minor value in the proposed form of this apparatus, if he shall be sufficiently pleased with the general conception to give it that attentive consideration which the importance of the object sought, if not any intrinsic merit or novelty in the method proposed, will justify.

In the accompanying engraving every part not essentially necessary to the exposition of the specific ideas of placing the furnace near the axis of the boiler, of discharging bodily into the water, and subsequently employing, as elastic bodies in the power of cylinders, the whole gaseous products of the combustion of the fuel; of conducting that combustion under a pressure of several atmospheres, has been intentionally omitted, from a conviction that any experienced engine-maker will readily supply such parts for himself if he shall be satisfied with the general soundness of the form of construction which I propose, and of my inferences of immense economical advantages due to it.

If, as I anticipate, experience shall demonstrate the economy of conducting the combustion under a very high pressure, say 200 or 300lbs. to the inch, it will be necessary to provide for closing the communication between the furnace and the boiler on each occasion of stoking, in order to save that loss of caloric which would be involved in the reduction of the pressure in the boiler from the high rate above supposed, to that of the external atmopshere. For this purpose a simple annular float, of a specific gravity slightly less than that of boiling water, embracing the furnace immediately below the bottom of the inverted dome-shaped furnace cover, and which would consequently be thrust into the bottom of the annular space between the furnace and the said cover, whenever the pressure in the furnace was reduced below that in the boiler (as it must be on each occasion of stoking), would suffice; and as the loss of elastic force incurred by opening the communication of the furnace with the external air would thus be limited to the measure of the quantity of condensed air actually in the furnace at the instant of opening the stoke pipe (the communication of the furnace with the condensed air chest having previously been cut off), I think it would be unnecessary to introduce an apparatus to supply the fuel without permitting the reduction of the pressure in the furnace; but if the latter object were very desirable, it could be effected without material difficulty.

I anticipate that in practice, a supply of fuel once in every hour will be found sufficient, and by suspending in a conical-shaped box immediately over the stoke pipe, prior to the removal of the cap from its top, the charge of fuel to be obtained, probably less than two minutes would elapse between the instant of unclosing and that of re-closing the said air-tight fitting cap after discharge of the fuel into the furnace, during which a greater or less diminution, but by no means a suspension of the development of elastic force, far superior to the current expenditure of two or three minutes' work of the engine, would always exist in the excess of the temperature of the water actually used, over that of water boiling under the pressure of the external atmosphere, but for marine, and probably other purposes, it may be found convenient to keep two distinct sets of boilers and furnaces in operation to supply one system of engines.

It has been suggested by some practical engineers who have examined my proposals, that under the high temperature and pressure at which it is proposed to conduct the combustion, a large amount of clinkers will be formed from the melting of the fuel, but a careful consideration of the subject has relieved me from much apprehension of such a result. On the contrary, I anticipate that a more perfect combustion than ever takes place under simple atmospheric pressure, will be found to result from the high pressure proposed to be employed, and consequently that the unconsumed residuum of the fuel exposed to such combustion will be confined to the most purely mineral and therefore incombustible matter.

Other engineers have suggested that the gases will carry with them, through the water into the power cylinders, such a quantity of the ashes of the fuel as will be very destructive to the polished surfaces of the different parts of the engine which may be reached by them; but when it is considered that the whole of such ashes as may be carried over the sides of the furnace will enter the water with a *descending motion*, that subsequently the bubbles of air in which it may be apprehended that they will be carried up through the water into the power cylinders, may be broken to any extent required by passing through any number of thin plates of metal, perforated with fine holes, which may be fixed in the water one over the other, I think there is little reason to apprehend that any mineral or gritty matter of *sensible volume* will ever be carried into the engine; on the contrary, I calculate that it will be quietly deposited on the bottom of the boiler by a continuation of the descending motion with which it will enter it, whence it can be discharged through the dirt pipe. This is essentially a smoke-consuming engine, of the most simple and effectual character.

The time may not be distant when, the apartments of our private residences being heated by small apparatus of this form of construction, whose volume will be measured by a few cubic inches, and daily consumption of fuel by ounces instead of by pounds, and power to give motion to the machinery of the numberless factories of our industry being generated by a smokeless and complete combustion of the fossil fuel, which was laid by for human use, in quantities inexhaustible, countless ages before the Omniscient Deity breathed the breath of life into the nostrils of the common parent of our race, the lurid clouds of unconsumed fuel which now pollute and oppress the atmos-

phere of our large cities, and poison the health of the millions of air-breathing men who toil therein, may pass from the catagory of the necessary physical conditions of urban life, into the pages of the historian of the progress of human society.

The following note was appended to a pamphlet published by Mr. Alexander Gordon, C.E., "On the Power of Heat for Propelling of Ships, and the Duty of a Cubic Foot of Coal. 1852:"—

An investigation of the volume, under normal atmospheric conditions, which will be assumed by the products of combustion of 1lb Jones' Anthracite Coal, and of the nitrogen which will be liberated from the oxygen in the atmospheric air required to support the combustion, by Mr. H. M. Lefroy, R.N. April, 1851.

The constituents of 1lb of this coal, as stated in Sir H. De la Beche's Report on Steam Coal, are:—

Carbon	0·9144lbs.	=1lb.
Hydrogen	0·0344	
Nitrogen	0·0021	
Sulphur	0·0079	
Oxygen	0·0258	
Ash	0·0152	

1 part of carbon combining with 2·66 parts of oxygen, the carbon above given will be converted into $0{\cdot}9144=(1+2{\cdot}66)=3{\cdot}346$lbs carbonic acid.

1 part hydrogen combining with 8 parts of oxygen, the hydrogen above given will be converted into $0{\cdot}0444\ (1+8)=0{\cdot}3114$lbs aqueous vapour.

21 parts of oxygen combining with 78 parts of nitrogen in atmospheric air, the nitrogen combined with the oxygen required to sustain the combustion of the carbon will be $0{\cdot}9144\times 2{\cdot}66\times\frac{78}{21}=9{\cdot}055$lbs.

Similarly the nitrogen in combination with the oxygen required to sustain the combustion of the hydrogen will be $0{\cdot}0346\times 8\times\frac{78}{21}=1{\cdot}029$lbs.

Therefore the total nitrogen contained in the closed furnace will be $0{\cdot}0021+9{\cdot}055+1{\cdot}029=10{\cdot}146$lbs.

13268 units of caloric are developed by the combustion of 1 part of carbon.

62470 units of caloric are developed by the combustion of 1 part of hydrogen.

Therefore the HEAT DEVELOPED by the conversion of the above given quantities of carbon and hydrogen into carbonic acid and steam respectively will be $0{\cdot}9144\times 13268+0{\cdot}0346\times 62470=14092$ units of caloric.

NOTE.—By unit of caloric is meant, throughout this investigation, that quantity which will raise the temperature of 1lb of water 1° Fahrenheit scale.

Under normal conditions—

The specific heat of water is	0·8470
" " nitrogen	0·2754
" " carbonic acid	0·2210
The coefficient of dilatation of water	0·003179
" " " nitrogen	0·003719
" " " carbonic acid	0·003719
The volume of 1lb of water (steam)	28·97 cubic ft
" " nitrogen	13·1 "
" " carbonic acid	8·36 "

MEETINGS FOR THE ENSUING WEEK.

MON. ...London Institution, 7. Prof. Tyndall, "On Light."

TUES. ...Civil Engineers, 8. Mr. M. Scott, "Description of a Breakwater at the Port of Blyth."
Pharmaceutical, 8.
Pathological, 8.

WED. ...London Institution, 3. Mr. T. R. Jones, "On the Natural History of the Vertebrate-Division of the Animal Kingdom."
Society of Arts, 8. Mr. P. A. Halkett, "On Guideway Agriculture."

THURS. ...London Institution, 7. Dr. E. Frankland, "On the Air and Water of Towns."

PATENT LAW AMENDMENT ACT.

APPLICATIONS FOR PATENTS AND PROTECTION ALLOWED.

[*From Gazette, Nov.* 26, 1858.]

Dated 31st July, 1858.

1740. C. de Bergue, Dowgate-hill, London—Imp. in submarine telegraphic cables, and in machinery for paying out or laying down the same.

Dated 2nd November, 1858.

2437. L. Beaver, Manchester, Lancashire—An imp. in sleeve-links.
2439. M. A. F. Mennons, Rue de l'Echiquier, Paris—An improved combination for the production of voltaic electricity, and its application as a curative agent to certain parts of the human body. (A com.)
2441. N. Brough, Birmingham—Certain imp. in buttons, and in the means of attaching them to garments, which said means is also applicable for other purposes.
2452. J. Lancaster, Belfast, Antrim—A new or improved method of driving and curbing horses.
2445. A. Barclay, Kilmarnock, Ayr, N.B.—Certain imp. in electric and magnetic, or electro-magnetic telegraphs, applicable to submarine and land communication.
2447. J. Sampson, J. Machon, and J. Bartholomew, Sheffield—Imp. in railway carriage brakes.
2449. N. S. Dodge, St. Paul's-churchyard—Imp. in treating waste vulcanised india-rubber. (A com.)

Dated 3rd November, 1858.

2451. C. F. O. Glassford, Greenwich—Imp. in the manufacture of manure from the excreta of towns.
2455. V. Blumberg, Bloomfield-lodge, Notting-hill—Imp. in the construction of slate billiard tables, which improvements are also applicable for other useful purposes.
2455. D. Fryer, T. L. C. Watt, and W. Holmes, Paternoster-row, —Imp. in tanning hides and skins.
2457. P. A. Mawdsley, Seacombe, Cheshire—The use or application of a certain substance or substances in the manufacture, stiffening, or sizing of paper.
2459. F. B. Busse, Carlton-terrace, Sydenham-park, Kent—Imp. in breech-loading fire-arms. (A com.)

Dated 4th November, 1858.

2461. J. Oxley, Camden-town—Imp. in carriages and wheel vehicles.
2463. G. A. Evelyn, Eccleston-terrace—The imp. of the form of the stocks of rifles, carabines, and other fire arms.
2465. C. Mather, Salford, Lancashire—Imp. in drying yarns while in the hank.
2467. R. A. Brooman, Fleet-street, London—Imp. in treating air and gases, and the employment of the same for obtaining motive power. (A com.)
2469. A. Friedmann, Frankfort-on-the-Maine—An imp. in bracelets, necklets, and rings.

Dated 5th November, 1858.

2471. T. Till, Hooper-street, Birmingham—Imp. in machinery for making nails, and for other analogous purposes where metal is compressed by dies or stamps.
2473. C. J. Tjador, Stockholm, Sweden—Imp. in gun carriages, and in apparatus for lessening recoil.
2475. D. McClure, Heaton Norris, Lancashire—An imp. in the machinery used for the drying of yarn, thread, cloth, or other wet fabrics.
2477. L. Schwartzkorf and F. C. Phillipson, Berlin—Imp. in machinery for boring holes in rocks and minerals, for blasting and other similar purposes.
2479. R. E. Pinhey, Woolstan, and J. Wood, High-street, Southampton—Imp. in apparatus for ascertaining the variation of ship's compasses for local errors.

Dated 6th November, 1858.

2481. H. N. Penrice, Witton-house, near Norwich—Imp. in machinery for tunnelling and driving galleries through rock and other strata.
2483. B. W. Jonas and R. Jones, Southwark, Surrey—An improved ship's block.
2485. J. Cliff, Lambeth, Surrey—Imp. in the construction of kilns for burning stoneware, red clay-ware, porcelain, and all other kinds of earthenware.
2487. W. Ziernogel, Hettstadt, near Eisleben, Prussia—Imps. in apparatus for distilling products from bituminous coal, schist, peat, and other like substances.
2489. J. Jackson, A. Fisher, and J. J. Harney, Sheffield—Imp. in the manufacture of strips or bands of steel, and in the machinery or apparatus to be employed therein.

Dated 8th November, 1858.

2491. J. Richmond, Carlisle-terrace, Fairfield-road, Bow, J. Quick, jun., and A. Frazer, Summer-street, Southwark—Construction of a meter for measuring water, spirits, or any other fluids.
2493. E. Alcan, Coleman-street-buildings, London—An improved method of treating or preparing materials to be manufactured into paper, applicable to lye-washings in general. (A com.)
2495. J. Wardill, Commercial-road, East—Imp. in purchases for the raising and lowering of weights by means of chains, especially applicable to ships' capstans and windlasses.